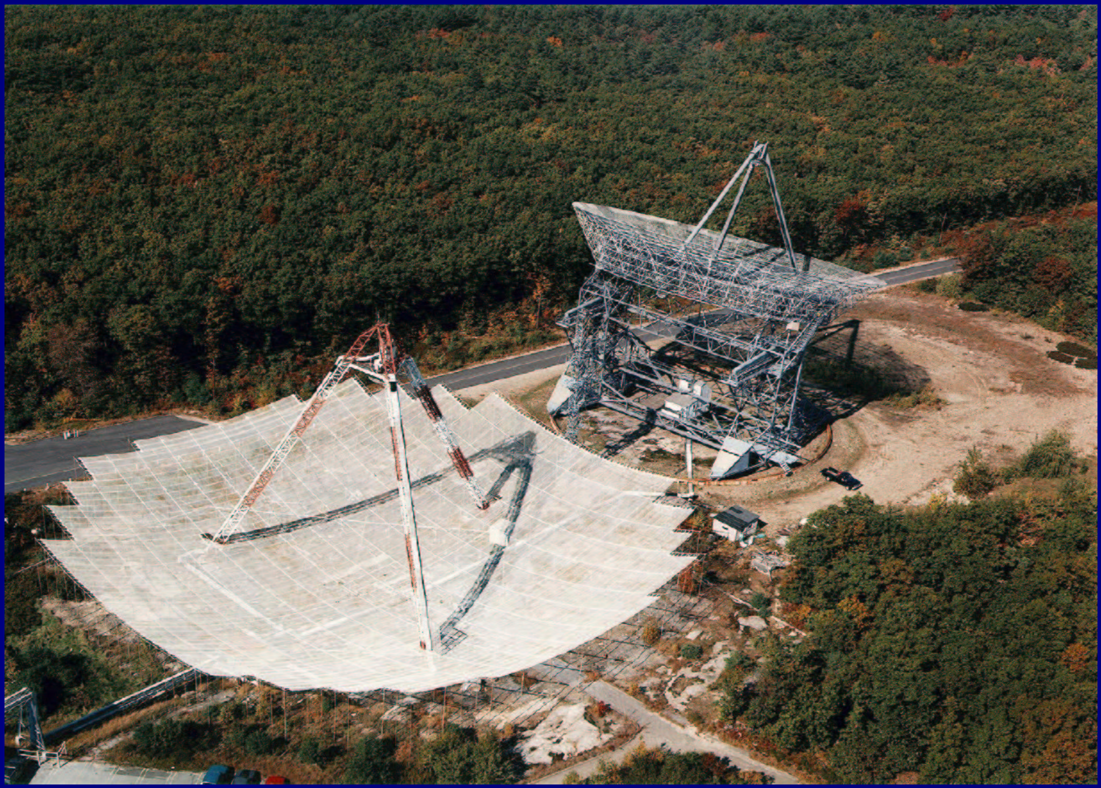
Software Radar Technology and The Open Radar Initiative



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Enabling Technologies for Next-Generation Radio Science

Exponential increase in network, storage, computational systems

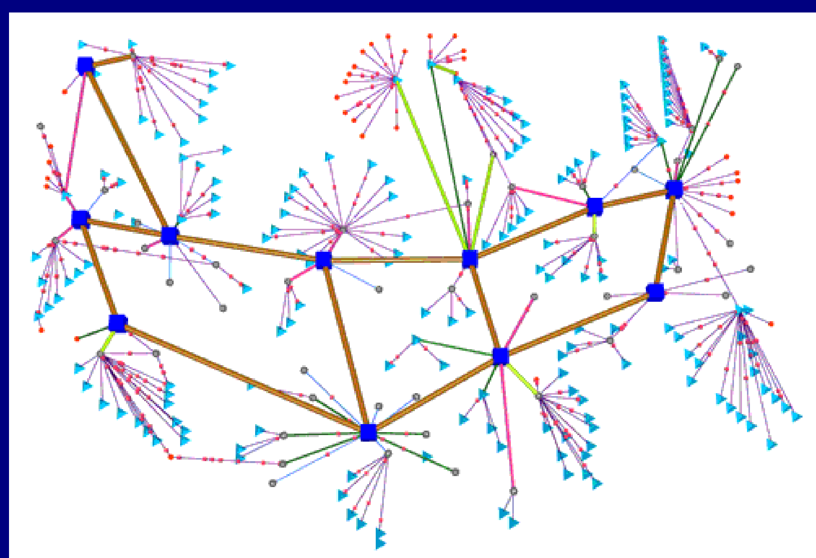
Wide-area networking - allows unified data transport / assimilation

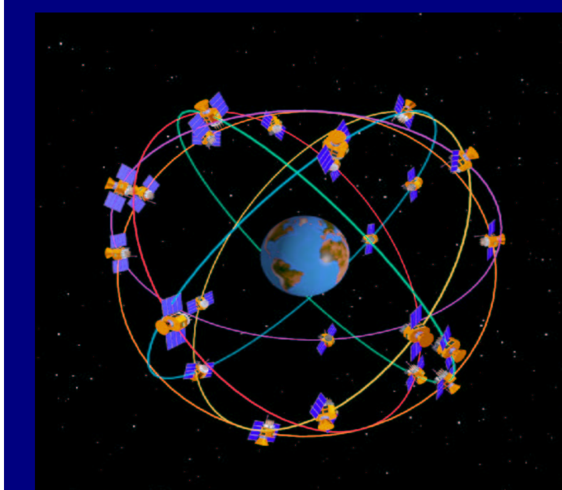
Global Positioning Systems - a true worldwide time reference

High performance digital receivers

High performance receiver front ends and filters

Open Source Software





Information Technology and Radio Science

Integrate information technology directly into instrumentation

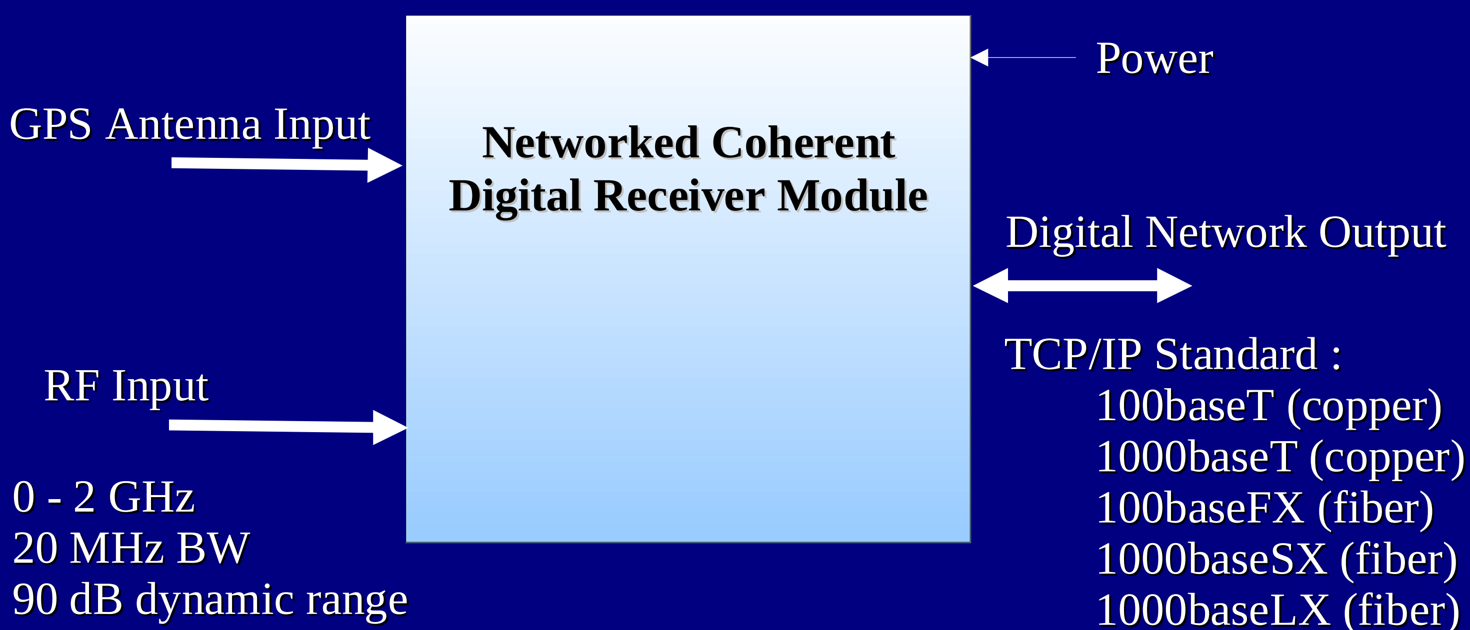
Instruments become network-aware and globally synchronous

Software integration allows for distributed operation and coordination

Distributed 'raw' information enables new applications

Meta-instruments can be dynamically created in software

The whole is greater than the sum of its parts!



Precise and Flexible Instrumentation

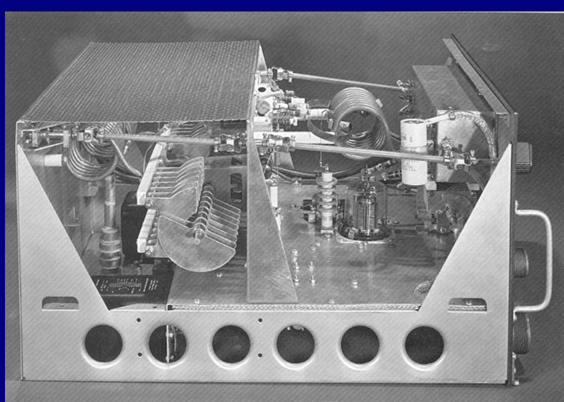
First-generation instrumentation : flexible but imprecise (analog)

Recent instrumentation : precise but inflexible (fixed digital controls)

Current instrumentation : precise and flexible (software integrated)

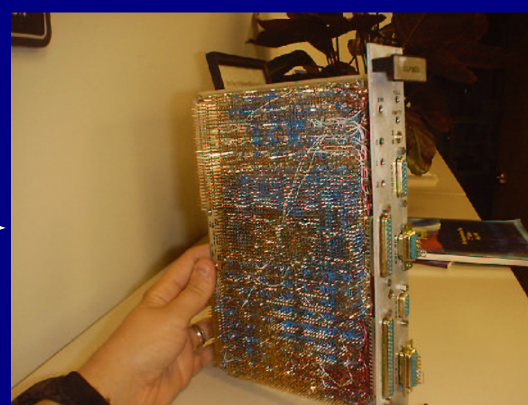
Future Instrumentation : precise, flexible, and intelligent (meta instruments)

(analog)



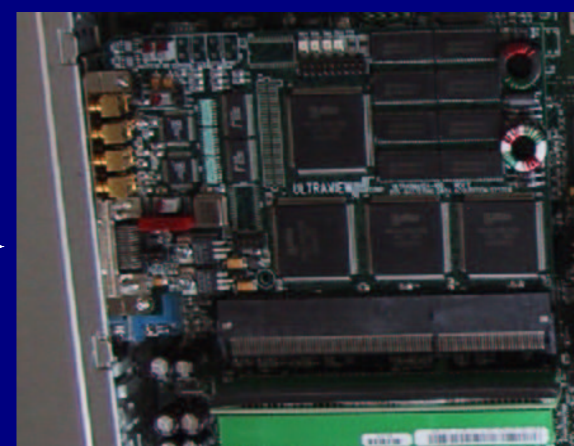
(18 MHz RF amplifier, mid-1950s)

(fixed digital controls)

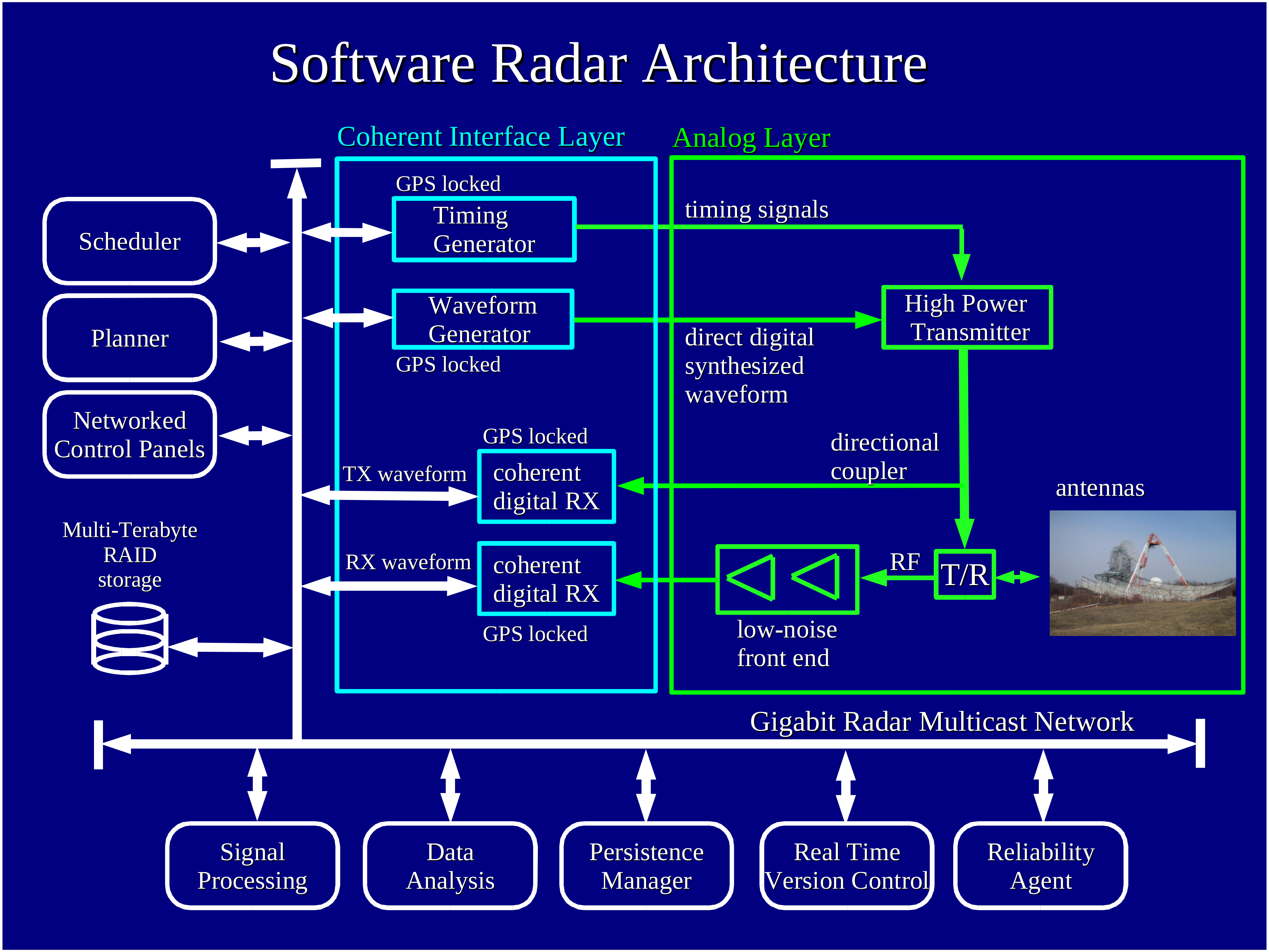


(MIDAS-1 signal proc. card, 1988)

(software integrated)



(Ultraview high speed A/D card, 1996)



Software Radar Architecture
Coherent Interface Layer
Analog Layer
Scheduler
Planner
Networked Control Panels
Multi-Terabyte RAID storage
GPS locked
Timing Generator
Waveform Generator
GPS locked
GPS locked
TX waveform
coherent digital RX
RX waveform
coherent digital RX
GPS locked
timing signals
High Power Transmitter
direct digital synthesized waveform
directional coupler
antennas
RF
T/R
low-noise front end
Gigabit Radar Multicast Network
Signal Processing
Data Analysis
Persistence Manager
Real Time Version Control
Reliability Agent

Software Radar as a Unifying Technology

Geographically distributed radars and receivers are unified.

Wide area phase and timing coherence enables meta-instruments.

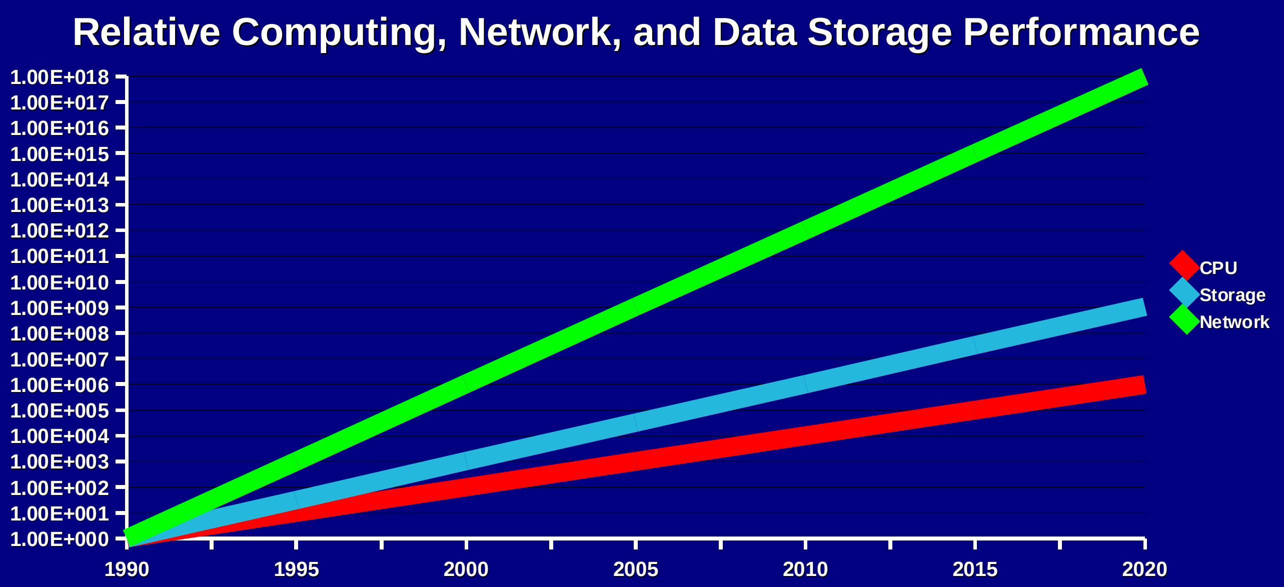
Transmission and reception are decoupled - easily accommodates multistatic geometries and passive radar.

Multi-channel architecture allows development pathways to coexist with stable operational systems.

Replay capability permits unique geophysical events to be analyzed in multiple ways which optimize science yields.

Robust fault-tolerant network architecture accommodates hardware and software failures through redundant systems.

Implementing a Software Radar System



For How Long?

Limited by Data Processing Performance Despite Moore's Law
With Some Effort Raw Data Can Be Stored For the Foreseeable Future
Continued Improvement in Software Radar Capabilities
Software and Algorithms are the Real Limitation

There is some hardware...

- Digital Receivers (up to 20 MHz RF bandwidth is easy, more is hard right now)
- Network Enabled Control Elements (integrate full computers into control elements)
- General Purpose CPUs for Data Processing (processing 2 MHz RF bandwidth/cpu in real time)
- Multi-Gigabit Network Switch (about 30 MHz RF bandwidth; 300 MHz RF bandwidth soon)
- Multi-Terabyte Data Stores (I/O limited to 10 MHz BW RAID 5, 25 MHZ BW RAID 0)

Software Tools for Software Radar

MULTICAST | **HTTP**

XDR | **XML**

Radio Science Object Namespace | **Object Transport Layer**

Device Interfaces
C, Python

- Antennas
- Transmitters
- Receivers
- RF Switches
- Sensors
- Panel Controls
- Panel Displays
- Safety Interlocks

System Components
C, Python

- Radio Signal Processing
- Radar Signal Processing
- Experiment Recording
- Experiment Playback
- Data Product Generation
- Data Management
- Radar Version Control

Component Glue
Python

- User Interfaces
- System Monitoring
- System Control
- Automated Testing
- Experiment Design
- Experiment Planning
- Experiment Operations
- Fault Management
- Database Interface

Less Code ⟷ **More Code**

Open Source Development Model

Radio Science Object Namespace

The Information Space Associated With Radio Science Instrumentation

- Defines how objects in the distributed system are named.
- Allows construction of Uniform Resource Indicators.
- Provides an organized structure for system persistence.

Uniform Resource Indicator (RFC2369)

<scheme>://<authority>/<path>?<query>

XML Namespace Configuration

- Allows for easy namespace definition by humans or machines.
- Can be version controlled (CVS) easily.
- Mappings between namespaces can be defined.

Namespace Elements

- Date representation is ISO 8601 (e.g. 2002-12-06)

<system>/<component>/<attribute>[/<date>][/<object>]

Examples

- http://midasw/antenna/pointing/2002-11-06/antp@1039194000.xml
- umtp://midasw/correlator/status/2002-11-06/
- file://midasw/system/configuration/midasw_namespace.xml

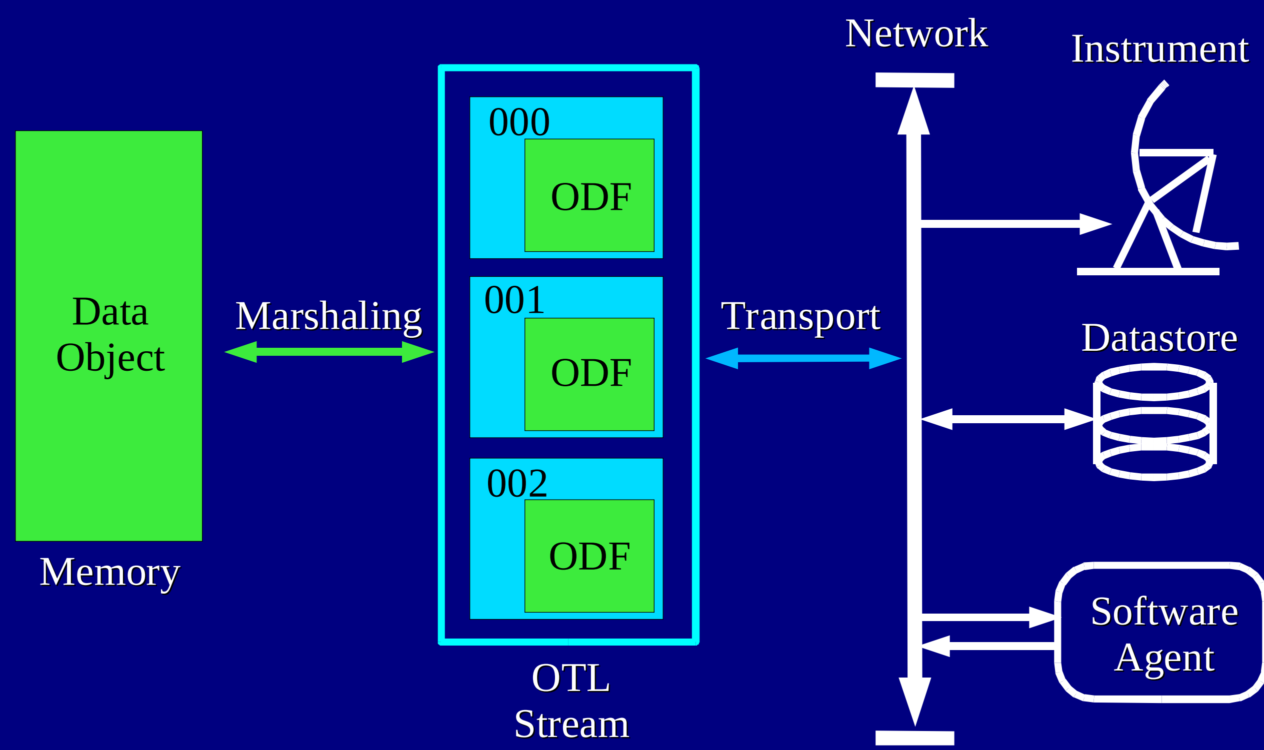
Object Transport Layer

Data Transport Layer for Real Time Instrumentation

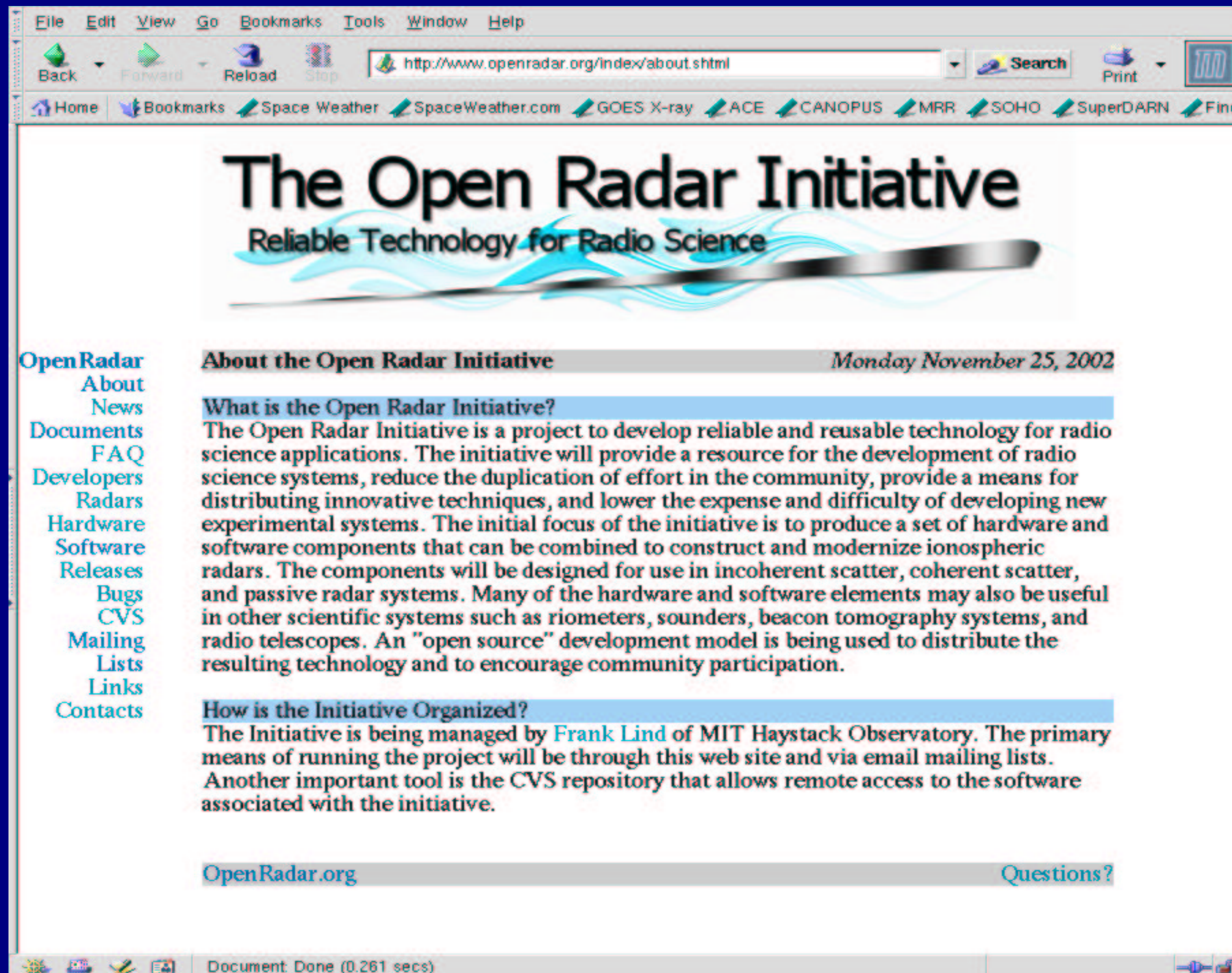
- Stream oriented transport and persistence of arbitrary objects.
- Packetized and Sequenced for unreliable multicast transport protocol.
- Reliable transports can be used when dropped data cannot be tolerated.
- Hyperlinking associates metadata with the information stream via URI.
- XML object definitions with XDR (binary) mappings.

Object Transport Layer Frame

- Sequence Number (64 bit)
- Second (64 bit)
- Nanosecond (32 bit)
- Hyperlink (256 byte)
- Object Type (32 bit)
- Object Size (32 bit)
- Frame Number (32 bit)
- Object Data Frame (XDR)



The Open Radar Initiative



The Open Radar Initiative

Reliable Technology for Radio Science

www.openradar.org

Summary

Software Radar Technology

- A Unifying Radar Architecture (active/passive, mono/multistatic)
- Instrumentation that is Precise, Flexible, and Intelligent
- Enables New Categories of Radio Science Instrumentation
- Infrastructure for a Global Radio Science Network

Software Radar Implementation

- Millstone Hill Incoherent Scatter Radar
- MIDAS-W (Millstone Data Acquisition System)
- Python, 'C', and XML
- Prototype Implementation of Software Radar Patterns
- Operational Since November 2001